DESIGN THINKING IMBEDDED IN PRODUCTS

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ABSTRACT

This study addresses new decision-making methods for concept selection within industrial design. For this purpose a framework capturing key user – product – provider aspects is developed, organizing designer's verbally expressed design-arguments. The pattern observed during initial testing is consistent with the authors' experiences from design consulting, encouraging further refinement and exploration. Based on the gained experience, the Concept Aspect Model is revised and a strategy is devised for further validation and connection of verbal design arguments with relevant external performance metrics.

Keywords: Evidence-based, concept-evaluation, concept-model, concept-profile, design argument, industrial-design

1   INTRODUCTION

At the end of the conceptual phase, and at the beginning of the design phase, designers traditionally present their concept ideas using images and storytelling. Within the design team, these concepts are internally down selected using feasibility and novelty criteria. Evaluating, comparing, combining and deciding which concepts to choose are currently accomplished using a combination of subjective criteria, intuition and social power. The present method of evaluation makes the final decision prone to situational mood swings, personal negotiation abilities, temporary corporate politics and context dependent preferences. Therefore, there is an opportunity for developing a more systematic framework for mapping design concepts and for presenting a method that makes evaluating the objective strength of competing concepts possible. This method will enable the decision-makers to decide with which concept or aspects of concepts to proceed based on objective measurements.

2   OBSERVING DESIGN IN PRODUCT DEVELOPMENT

The research methodology consists of an auditing of past projects, interviews with actors on current product development projects and a brief literature review of product development literature. Based on the findings, a framework for evaluation of concepts is formulated and tested against academic and industry expert's experiences from design consulting.

To provide an overview of problems occurring in present product development, a general qualitative audit of past projects was completed, followed buy a focused quantitative audit on recent projects. The development projects reviewed were executed within consumer products and carried out at a large Southern California design consultancy. The material analyzed was digitally recorded after action reviews were recorded and documented by the first author. Analysis procedure was a coding of failures followed by a mapping of these relationships.

2.1 Reviewing product development projects

First a quantitative audit of 66 past product development projects, executed during a four-year period from 1999-2003, was conducted. The first author's involvement on these projects ranged from two days to one year and his contribution covered the length of the product development process. The majority of critical problems identified could be traced to the conceptual phase.

Based on the finding from the first study, a second qualitative audit was conducted on ten recent projects, with focus on the conceptual phase. The projects examined were executed during the period

2004 – 2007 and 29 problems were detected. Of these, seventeen problems (about 60%) could be traced to the decision-making in the conceptual phase.

Problems here resulted from lack of formulation of criteria for concept exploration, lack of clear decision-criteria and failure to use a systematic decision-making process. Concept selection was done, on a hunch, by elimination concepts, which did not seem immediately feasible. Additionally there was no built-in validation procedure.

Problems resulting from this approach were the pursuit of unclear and unfeasible directions. This resulted in multiple reiterations of the chosen concept, often compromising elements that had originally made the concept unique. Yet, by this point in the development process, the team is reluctant to return and address the concept selection.

2.2 Designers concept search and evaluation

To understand the specifics of concept selection, interviews were conducted with thirteen professionals on projects at a large California based design office. Those interviewed, were two engineers, three managers, one design strategist and six designers, providing multiple perspectives on design. To obtain a quantitative impression of the early concept phase, interviews were informal with an open-ended interview guide. The focus of the interview was on concept generation and decision-making. Interviewees were asked to reflect on a recent project, making their opinions and feelings specific. The following aspects were addressed in the fourteen projects covered:

- How the design was developed
- How design solutions were quantified
- How decisions were made
- The outcome of project
- Suggestions to improve the process

Following the interview, the digital records were analyzed for key statements and these were then grouped into overarching categories. The resulting categories were: "Specific observations" and "Unaddressed observations."

2.2.1 specific observations, - what the designers observed as issues

From each group, statements representing the specific issues were subtracted, consolidated and listed in the following outlines:

Question 1 - Concepts: What is a concept? What elements have to be included to constitute a concept?

Answer 1:
- Concepts are developed themes

This definition articulated by the subjects is both general and ambiguous, making upcoming analysis difficult.

Question 2 - Process: What are the characteristics of the design process, the tools, and the steps?

Answer 2:
- State the problem in such a way that it doesn't dictate the solution
- Move from no criteria or limited criteria, then tighten up as one progresses
- When developing concepts, it is useful to come from a position of aspiration and then move toward reality
- Build on others ideas at reviews and through informal conversations
- Form follows function
- Show bandwidth/ boundaries

These general statements express the subject's perception of the design processes as aiming at a broad, unbiased, collaborative diverging/convergent synthesis thinking with concurrent developed criteria and selection, based function and feature.

Question 3 - Criteria: Which criteria do designers use when developing and evaluating and preparing arguments for design concepts?

Answer 3:
- System context
- Number of derivatives
- Innovation
- Manufacturing issues
- Functionality
- Value
- Cost
- Usability
- Aesthetic (no metric, subjective)
- Authenticity (no metric, subjective)
- Create an icon (no metric, subjective)
- Creating tension, automotive design (no metric, subjective)
- Heritage (no metric, subjective)

Based on personal knowledge from design education and product development practice, the last five of the thirteen criteria have no objective metric. This highlights the inherent difficulty in making good decisions.

Question 4 - Evaluation: What does the concept evaluation procedure look like and what are the opportunities?

Answer 4:
- Client doesn't always know what he wants
- Designers compete against one another and want to have their concept chosen, or to "win"
- Lead client from a familiar idea to a new idea
- Show bandwidth/ boundaries
- Trust in the person behind the design is everything
- Design by committee dilutes the design
- Deferring the hard stuff till later
- Often, little time is set aside for developing a story and the story is made up on the spot at the time of presentation

The subjects' description of the decision-making process highlights the inherent difficulty in concept selection. The challenges include ambiguity of customer requests, the adversarial relationships in the teams, the education of the client while selecting concepts and the desirability of diversity. Arguments and concept ratings are based on a designer's integrity, with no built-in systematic or objective evaluation. Consensus decisions are viewed as diluting the concepts. Problems are avoided and deferred to later phases.

2.2.2. Observations not addressed by the designers and engineers
The following are example of issues the designers and engineers did not address:

- Did we consider the right technology?
- Is this really the right functionality for the client?
- Are we solving the right issues?
- Are the right people present at the decision-making?

The fact that the importance of technology, other than, "form follows function," was not mentioned in the interviews further highlights the designer's focus on the user. Technology had not been considered by designers and had often been relegated to the engineers.

The main conclusions of this study are that industrial designers argue their design concepts, during presentations, using story telling. Based on these design arguments and strictly on the gut-feelings of strong personalities, concepts are down selected. Conducting thirteen informal interviews with professional designers and engineers failed to provide insight into more optimal decision-making procedures in the conceptual phase.

A brief review of collected literature on design, [1] - [12], provided no insights on the field of concept quantification. Normative decision-theory offers an approach. The challenge of assigning preference probabilities to the various aspects, however, is inherently difficult and subjective.

Is it possible to change the way in which designers fundamentally think and argue design to fit into a predefined framework? Or, would it be better to develop an approach that will utilize their current communication style? Because my experience with people has led me to conclude that it is practically impossible to change their behavior after a certain mindset has emerged, I opted for the latter approach. If the design concept decision-making could be improved and perhaps evaluated through some form of visual pattern recognition framework conducive to the designer's visual thinking style, current design challenges could be reduced or eliminated altogether.

3 DEVELOPMENT OF CONCEPT ASPECT MODEL

3.1 Selection of the Concept Aspect Model (CAM)
Today, when a client reviews concepts, communicated as sketches or renderings, generally these act as footprints of a decision-process or a one-text-procedure [13], used in negotiation theory. These do not relay the thought process and assumptions behind the concept. Such thoughts are relayed in verbal storytelling, making it difficult to compare one story to another or integrate two stories into one stronger story. This led me to ask the question: Does an objective complete construct of aspects exist, a Concept Aspect Model (CAM), which exhaustively captures the designers' verbal design concept arguments, providing an internal concept metric to explore hereafter? Preferably this construct should correlate with industry-accepted criteria? In order to answer this question it is important to understand how concepts are selected in the early concept phase today.

Inspired by the findings of the three studies and the literature review, 11 frameworks were proposed for evaluating verbal design arguments [14]. Using the assessment of three experts from academia as well as industry, including the author, the frameworks were rated. The Concept Aspect Model (CAM) was marginally rated highest. See Table 1.

Table 1. Ranking of proposed frameworks according to the key applicability criteria: Objectivity, relevance, quantitatively and existing body of knowledge

Alternative Frameworks Degree of performance, from 0 to +++		Objective	Quantitative	Relevant	Existing knowledge	Total
1	Concept Aspect Model	++	+++	+++	+++	11+
2	Concept Aspect - Matrix	++	++	++	++	8+
3	C-K theory and Concept Aspect Model	++	++	++	++	8+
4	Anthropomorphic Association Model	++	+	+	+	5+
5	Meyers-Briggs Model	+	+	+	+	4+
6	Sustainable Management System Model	++	++	+++	++	9+
7	Question-Asking Concept Quality	++	++	++	++	8+
8	Human Factors Model	++	+	+	++	6+
9	Process Model	+	+	+	++	5+
10	History - Tactic Model	++	+	++	+	6+
11	Contradiction Model	++	++	++	++	8+

The categories "Objective" and "Quantitative" were selected based on these being the key issues in the majority of the problems detected in the conceptual phase. "Relevant" and "Existing Knowledge" was selected based on the tactic of accelerating the research. Focusing on the conceptual phase only and eliminating further research prior to validation of model, a quick first evaluation could be made. Consequently, due to the course rating system, it was decided to follow the Stanford/IDEO prototyping strategy "fail early - fail often". The Concept Aspect Model was selected for further exploration, with four close ranking fallback options, whereby the Sustainable management System Model represented the next candidate for testing.

3.2 Detailing of the Concept Aspect Model
The initially proposed CAM frames the concepts as a meeting between a user and an organization, each with its own internal progression of product aspects. These thirteen aspects are collected from user, product and provider characteristics, established in the product development literature [15], [16] and [17]. The details of the construction of the CAM are given in [18]. See Figure 1.
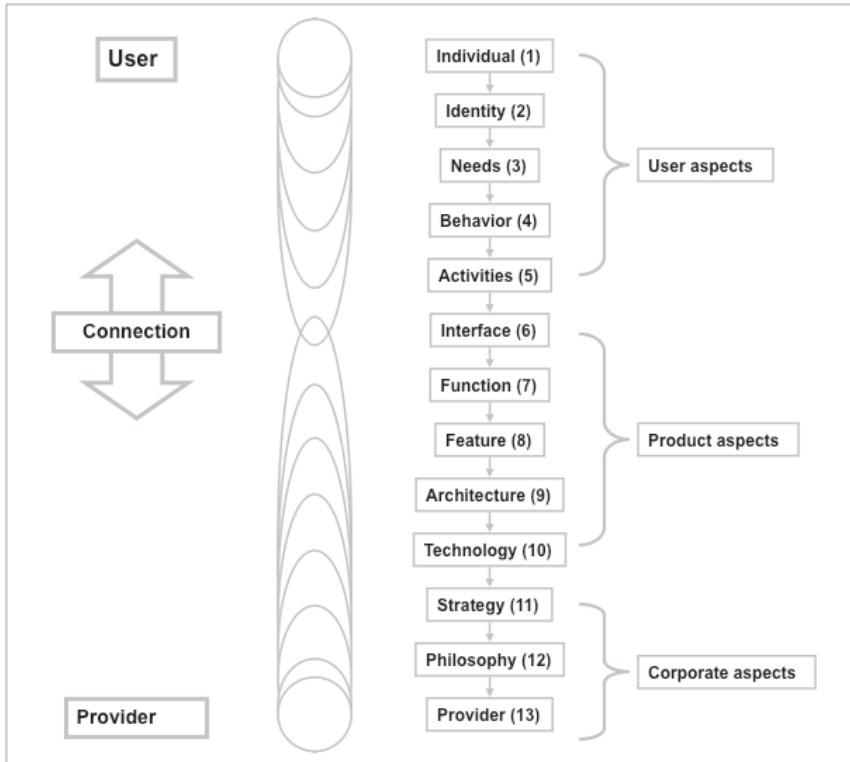
Figure 1. Concept Aspect Model progressive structure. At the core, the user and the provider meet at the product interface. Successive levels of aspects are a subcategory of the previous level.

3.3 Testing of Concept Aspect Model

The model was tested in the field for its practical relevance in studies using open-ended semi-structured interview guides. Data on fifty initial concepts were collected on ongoing projects and coded according to the framework's prescribed aspects. These concepts represented consumer centric products, such as printers, vacuum cleaners, medication devices, furniture and automobiles.

The projects were randomly collected on industry product development projects at leading industrial design companies in Southern California in conjunction with industry-sponsored student projects at renowned design and engineering schools. Interview subjects were semi-randomly selected (randomly approached, as needed, in the immediate available environment). All were friendly or neutral towards the interviewer, the first author.

4   FINDINGS AND REFINEMENT OF CONCEPT ASPECT MODEL

As an initial assessment of the framework's ability to differentiate between concepts, the collected designer's concepts were grouped into broad categories based on industry-recognized characteristics. Concept patterns showed significant differences along predicted aspects, providing first confidence in the framework [18].

4.1 Design in cultural content

Comparison of Concept Aspect Profiles from students at Stanford, Art Center and the Danish Design School, showed Stanford students emphasize "Identity," "Behavior" and "Philosophy." Art Center students emphasize aspects relating to the "Provider." While Danish Design School students emphasize "Individual," "Interface" and "Function". These observations was statistically significant at

a $p<0.05$ level and generally correspond with the reputation of and the first author's personal close experience with the three universities.

4.2 Design vs. Styling

Comparing Concept Aspect Profiles from students engaged in product design and automotive design at Art Center, showed product students emphasize "User in Context", "Individual," "Need" and "Interface," while automotive design students' emphasize "Identity," "Behavior," "Architecture" and "Philosophy". The stronger focus of product design students on "Interface" as compared to automotive designers together with automotive design students' stronger focus on "Architecture" was not surprising. "Interface is key to products as is vehicle "Architecture" of cars, which to a large extent, drives their styling opportunities. These observations were statistically significant at a $p<0.05$ level.

4.3 Professionals vs. Novices

Comparing professional designers and novice designers Concept Aspect Profile, showed professionals to have a stronger focus on "Needs" and "Function," while novice designers focus more on the "Individual's" relationship to society and "Behavior" and "Activity." These findings corresponded with our expectations from the field. This difference was statistically significant at a $p<0.05$ level.

4.4 Incremental vs. Innovative concepts

Comparing Concept Aspect profiles for incremental design concepts with those of innovative concepts revealed the only difference to be in the focus on "Behavior". For innovative concepts, "Behavior" was three times as strong. This was statistically significant at a $p<0.01$ levels

4.5. Refinement of Concept Aspect Model

Based on the above review of the preliminary Concept Aspect Model, the following modifications have been made as illustrated in Figure 2. The linear structure has been changed to a circular structure with two meeting points between user and organization, a transactional and a cultural. Furthermore, the component "Process" has been added to "Strategy," renaming this aspect "Planning." The expanded framework accounts for the physical as well as contextual relationship along with the influence that the development process had on a concept and final product. We now have the Concept Aspect Model.
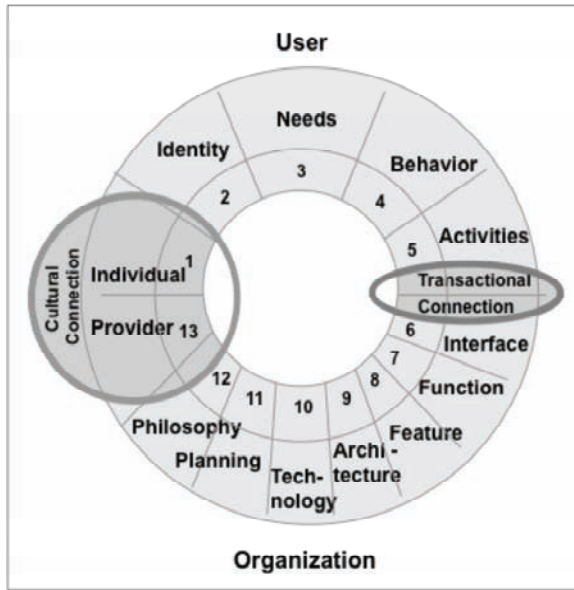
Figure 2. The circular Concept Aspect coding, describe how
users and providers connect at a transactional and cultural
point.

5   DISCUSSION

5.1 Reliability of data in relationship to measurement

In developing the interview guide, great care was taken to cover all relevant areas of a products performance. However, it is possible that the structures of the questions are biased towards certain aspects, causing these to receive a higher number of information segments. Further studies will have to be carried out to evaluate this and to correct for bias. However, with the aggregated profile representing the interview instrument bias, dividing the baseline into each Concept Aspect Profile could provide the necessary corrections.

Another issue is the interviewee's ability to comprehend and articulate his answer. More abstract questions, such as related to philosophy, might take more information segments to communicate, resulting in such an aspect receiving a higher focus.

It would also seem unlikely that all information segments carry equal weight. As an example, a statement dealing with an interface detail such as an edge and corner radii, could receive the same information segment count as a statement covering an ergonomic form development, making it more usable for elderly.

It seems quite unlikely that information segment distribution and importance is linear dependent, in part due to repetition. Therefore the contribution could be tapering off, offering only incremental contribution as the count increases.

5.2 Reliability of data as to sample size

At this stage the data set is limited, with fifty interviews with approximately 100 – 130 information segments per interview. Questions such as, how accurately people articulate their design arguments? What are the variations in their ability to argue for their concept? Does the repeating their arguments, or parts thereof, later in the interview result in introducing inaccuracies? Again, further studies, with a more narrow focus on similar projects and larger sample sizes are necessary for drawing meaningful conclusions to these questions.

5.3 Reliability of coding

By re-coding five of the interviews a year after the initial coding, it was possible to evaluate reliability with which a person can perform this task. The average correlation was 0.77, reflecting an 88% coding accuracy. Inviting two additional people to code an interview resulted in low correlations between initial coding and those done a year later. This shows that while reliable coding can be performed, it requires expert knowledge and experience in the field of design.

6   CONCLUSION

From the interviews conducted with designers and engineers at a large design consultancy, it is clear that the decision-making process in the conceptual phase presents opportunities. Here the CAM has been shown to be useful while asking for further improvement. Designers' definition of the term concept itself is ambiguous: "Concepts are developed themes." Furthermore, five of the thirteen criteria (37%) for choosing a design concept currently have no metrics that facilitate evaluations. In addition, in the evaluation of concepts they use none of the established decision-making processes, like weight/ranking, probability preferences or decision trees.

The logic, in the form of a story supporting a concept is formulated and presented by the designer. Various designs show bandwidth and are therefore difficult to compare and evaluate. Decision-making was mainly based on the clients' criteria and emotions/intuition. They are strongly influenced by opinions and strong personalities and their hunches, gut feelings, personal aesthetic preferences and emotional states. Concept selection is carried out by elimination of weaker concepts, rather than by choosing the strongest ones. The concepts that move forward represent a bandwidth of possible solutions. Downstream deviations from an initial concept and subsequent consequences are difficult to evaluate.

Based on above observations and interviews, there is a definite opportunity to develop a methodology for quantifying design parameters in the conceptual phase of the development process. The methodology focuses on measuring the concepts' level of design quality and relates this to external performance metrics.

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